ZVT-ZCT PWM DC-DC BOOST CONVERTER WITH HIGH EFFICIENCY

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Abstract- An improved active snubber cell is proposed for ZVT-ZCT PWM DC-DC boost converter. Zero voltage transition (ZVT) turn on and zero current transition (ZCT) turn off is provided by this active snubber cell. There is no extra current or voltage stresses on the main switch. Also, zero current switching (ZCS) turn on ZCT turn off is provided for the auxiliary switch. Although there is no extra voltage stress on the auxiliary switch, a current stress is present. However, auxiliary switch current stress is decreased by coupling inductance. The coupling inductance transfers the part of the current stress to the output load according to the transform ratio. So, the converter efficiency is improved. Experimental application is proved by 300 W prototype with 100 Khz switching frequency. As a result, improved ZVT-ZCT PWM boost converter is reached 98,8% total efficiency at full load with decreased current stress.

Key words- active snubber, ZCS, ZCT, ZVS and ZVT.

I. INTRODUCTION

Nearly all electronic systems use DC power as an energy source. Also, DC-DC converter is required for fast and easy control with high reliability. Fast control needs high switching frequency for the converter. High switching frequency also causes electromagnetic interference (EMI) and extra switching losses [1]. Normally current and voltage waveforms overlap in every switching action which is called hard switching. Addition to overlap power loss at hard switching, reverse recovery loss of diodes and parasitic capacitance discharge loss of the main switch is taken into account for general power loss in switching process. Nowadays, to overcome these drawbacks, soft switching techniques are used. Soft switching techniques provide high efficiency due to lowered or destroyed current or voltage stresses [1-17]. There are mainly four soft switching techniques which are zero current transition (ZCT), zero voltage transition (ZVT), zero current switching (ZCS) and zero voltage switching (ZVS). For ZCT and ZVT techniques power loss can be gained back again, however for ZCS and ZVS techniques only power loss can be lowered [6-8, 13, 15-17].

The proposed converter in [8], main switch ZVT turn on and ZCT turn off , auxiliary switch ZCS turn on and ZCT turn off are provided. Although ZVT-ZCT soft switching tecniques improve the efficiency, the current stress on the main switch is two times more than the input current. Nevertheless, extra current stress is present on the auxiliary switch. Because, these extra current stresses affects converter reliability and performance, the system efficiency is 98,3% at full load.

The proposed converter in [13], ZVT isolated boost converter is explained, however only ZVT turn on of active switches are achieved. Although ZVS soft switchings is provided for main and clamp switches, diodes power loss is present by the reverse recovery problem. The main switch and the auxiliary switch extra current stresses are still present for the proposed converter. So, the efficiency of the proposed converter is around 96% at full load.

The proposed system in [15], ZCS PWM DC-DC boost converter provides ZCS turn on and ZCT turn off for the main switch. However there is an extra current stress on the main switch due to resonance. The auxiliary switch has no advantage of soft switching. So hard switching apply to the auxiliary switch. Clamping diode assisted ZCS
PWM conveter has 98.4% total efficiency at full load.

The proposed converter in [16], capacitor cell assisted soft switching PWM DC-DC converter is explained. The main switch ZCS turn on and ZVS turn off processes are achieved, however extra current and voltage stresses are present both for the main and the auxilairy switch. Additionally, high circulating current is present for the main and the auxiliary switches. The efficiency of the converter is about 96%.

The proposed system in [17], the main switch ZVT turn on and ZCT turn off are provided. However, for the auxiliary switch ZCS turn on and nearly ZCS turn off are provided. Although there is no extra current stress on the main switch and lowered current stress on auxilary switch, the system efficiency is 98%. On the other hand, the proposed system is realized as AC-DC PFC converter which is controlled to get unity power factor at the AC mains.

The aim of this study is to improve PWM DC-DC boost converter topology with ZVT-ZCT soft switching techniques. As presented in here, the published converters have extra current and/or voltage stresses even if they use soft switching techniques. So, a new active snubber cell is proposed to solve these problems. In the proposed active cell, main switch ZVT turn on and ZCT turn off, auxiliary switch ZCS turn on and ZCT turn off are provided respectively. The main switch extra current and

voltage stresses are eliminated. The auxiliary switch voltage stress is eliminated and current stress is lowered by the coupling inductances in the snubber cell. The current stress in the auxiliary switch is lowered by the coupling effect. Depend on coupling inductance transform ratio, current stress is transferred to the output load. So, switching power loss is lowered and efficiency is improved. Also, by adding the D2 diode serially to the auxiliary switch path, incoming current stresses from the resonant circuit is prevented for
to the main switch. Also the control strategy is improved by sensitive switching moments. As a result, the proposed converter system has 98,8% efficiency at full load. To verify this theoretical analysis, 300 W with 100 kHz ZVT-ZCT PWM DC-DC boost converter is realized.

II. ADVANTAGES OF THE PROPOSED CONVERTER

Although there are some ZVT-ZCT DC-DC boost converters in literature, the proposed converter get full benefits of them. As a result, advanced soft switching techniques are used for the proposed converter not only for lowering the current stress on power switches but also improving the efficiency.

1. The main switch is turned on with ZVT and turned off with ZCT.
2. The auxiliary switch is turned on with ZCS and turned off with ZCT.
3. The main diode is turned on with ZVS and turned off with ZCS and ZVS.
4. The main switch extra voltage and current stress are disappeared.
5. The auxiliary switch extra voltage stress is disappeared and current stress is lowered by the coupling inductances.
6. The main diode extra voltage and current stress is disappeared.
7. S2 switching frequency is two times of S1 switching frequency.
8. High switching frequency gives advantage of fast control and high power density with lowered component values.
9. Although soft switched active snubber cell is used in the proposed converter, total time interval is sufficienctly small to work as normal PWM control.
10. Except D2, SIC diodes are used in the converter to provide better reverse recovery power loss.
11. The proposed active snubber cell can be used for higher power levels for many DC-DC PWM converters.

III. APPLICATION CIRCUIT AND EXPERIMENTAL RESULTS

A prototype of 300 W and 100 kHz DC-DC boost converter is shown in Figure 1 to verify the predicted analysis of the proposed converter. The converter is obtained by adding ZVT-ZCT-PWM active snubber circuit to the DC-DC boost converter. The boost converter consists of the main inductance LF, the main switch S1 and the main diode DF. The active snubber circuit consists of the auxiliary switch S2, four auxiliary diodes D1, D2, D3,and D4, the snubber inductances LR1 and LR2 with the coupling inductance and the snubber capacitor CR. Resistive load is aplied to the output of the converter.

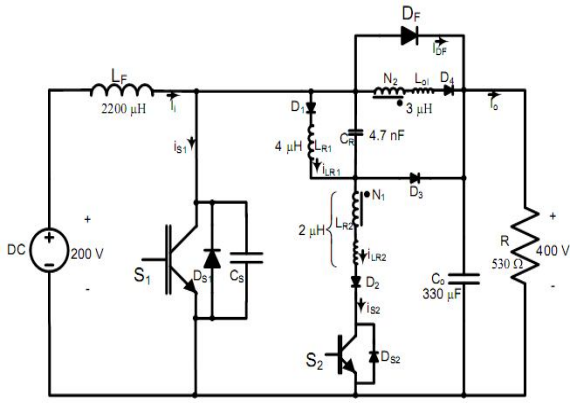


Figure 1. The prototype circuit scheme of the proposed converter.

The value of 200 V DC is applied to the input of the boost converter. The LF main inductance is calculated to process continues current mode (CCM) and chosen as 2200 µH. The LR1 snubber inductance of the snubber circuit was chosen as 4
µH, the LR2 snubber inductance as 2 µH, Lol the coupling inductance as 3 µH, the CR snubber capacitor as 4.7 nF, output capacitor Co as 330 µF.
The auxiliary switch operates twice in one switching cycle of the main switch and the main switch operates at 100 kHz. During the turn on and turn off processes of the main switch S1, its body diode is turned on. Therefore, ZVT turn on and ZCT turn off processes are perfectly realized for the main switch S1.
The auxiliary switch is operated in both ZVT and ZCT processes of the main switch S1 so, the auxiliary switch is operated at 200 kHz. Both ZVT and ZCT operations of the main switch, the conduction time of the auxiliary switch is very short. The auxiliary switch is turned on and off under ZCS and ZCT respectively. Because the loss of the resonance circuit, the peak current of S2 in the ZCT interval is lower than the ZVT interval. And also the coupling inductance transfers the resonance energy to the output load for better efficieny. However, there are no additional voltage stresses on the semiconductors while the active snubber circuit operates under soft switching.
The main diode is turned on under ZVS and turned off under ZCS and ZVS. For the main and the auxiliary diodes, Silicone Carbide (SIC) diodes are used. SIC diodes have greater reverse recovery time with 10 ns.

In both ZVT and ZCT intervals, when the S2 is turned on, the voltage across the snubber capacitor starts to increase and when the S2 is turned off, the voltage drops to zero.

As an example, the voltage and current waveforms of the main switch S1 is taken at 20% rated load for ZVT turn on in Fig 2(a) and for ZCT turn off in Fig. 2 (b). It can be seen from Fig. 2(a) and Fig. 2(b), the proposed converter can work at light load conditions without any problem.

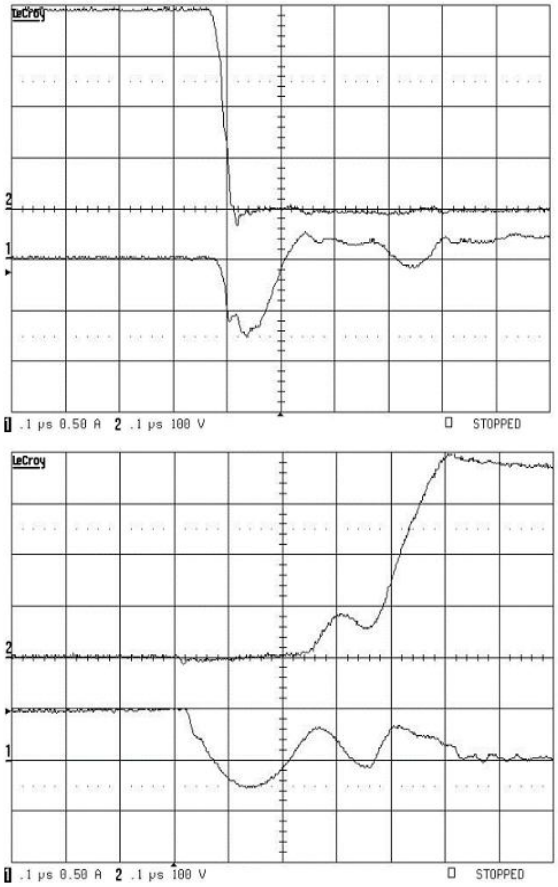


Figure 2. Voltage and current waveforms of S1 at 20% rated load a) ZVT turn on with the scales of 100 V/div and 0.5 A/div b) ZCT turn off with the scales of 100 V/div and 0.5 A/div.

CONCLUSION

In this study, a new active snubber circuit is used for DC-DC converters. For this purpose, only one auxiliary switch and one resonant circuit is used. The main switch and all the other semiconductors are switched by ZVT and ZCT techniques. The converter is realized with 200 V DC, to provide 400 V DC output. The converter is switched with 100 kHz for 300 W output load.

The main switch is turned on with ZVT and turned off with ZCT, the auxiliary switch is

turned on and turned off with ZCS. Also, all other semiconductors are switched with soft switching even at light load conditions. A part of the current on the auxiliary switch is transferred to the output load by the coupling inductance to improve the efficiency of the converter. The diode is added serially to the auxiliary switch path to prevent the incoming current stresses from the resonant circuit to the main switch. There are absolutely no current

or voltage stresses on the main switch. Although there is no additional voltage stress on the auxiliary switch, the current stress is reduced by transferring this energy to the output load by the coupling inductance. The improved switching strategy with sensitive switching moments. As a result, 98,8 % efficiency at full load is achieved.

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